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Flight Service Evaluation of Kevlar-49 Epoxy Composite Panels in Wide-bodied Commercial Transport Aircraft

Seventh Annual Flight Service Report

R. H. Stone

LOCKHEED-CALIFORNIA COMPANY
BURBANK, CALIFORNIA

CONTRACT (NAS1-11621)
April 1981

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National Aeronautics and
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N81 - 30186 #

FOREWORD

This is the seventh annual flight service evaluation report on the condition of Kevlar-49 fairing panels installed on three L-1011s under NASA Contract NAS1-11621, "Flight Service Evaluation of Kevlar-49 Composite Panels in Wide-Body Commercial Transport Aircraft." The manufacture and installation of these panels was completed in February 1973 and reported in NASA CR-112250 dated March 1973 (reference 1). The results of inspections after the first six years of flight service were reported in reference 2 through 7. The original 5-year flight service program was extended for an additional 5 years through 1983. Annual reports will be issued describing service performance after each year of service through the 10 year duration of the program.

This program is being administered by the Langley Research Center, National Aeronautics and Space Administration, with Mr. Benson Dexter of the Materials Division as the Project Engineer.

This program is being performed by the Lockheed-California Company with Robert H. Stone the Program Leader, assisted by G. R. Meyer of the Product Support Branch.

Use of commercial products or names of manufacturers in this report does not constitute official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration.

TABLE OF CONTENTS

	Page
FOREWORD	iii
LIST OF FIGURES	vii
INTRODUCTION AND BACKGROUND	1
PANEL INSPECTIONS	6
DISCUSSION OF INSPECTION RESULTS	8
SUMMARY OF RESULTS AND CONCLUSIONS	11
APPENDIX A - DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - AIR CANADA SHIP CF-TNB-502 (Serial 1021)	13
APPENDIX B - DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - TWA SHIP N31030 (Serial 1111)	20
REFERENCES	26

LIST OF FIGURES

Figure		Page
1	Right-Hand Wing-Body Fairing Panel	2
2	Right-Hand Underwing Fillet Panel	2
3	Left-Hand Aft Engine Fairing Panel	4
4	Air Canada Left-Hand Wing-Body Fairing - Deep Gouge 0.4 by 0.6 cm (5/32 by 1/4 in.)	16
5	Air Canada Left-Hand Wing-Body Fairing - Inner Surface Crack 1.3 cm (0.5 in.) in Length	16
6	Air Canada Left-Hand Wing-Body Fairing - Fastener Holes on Lower Edge with Mark-off	17
7	Air Canada Left-Hand Underwing Fillet with Elongated Hole and Slight Fraying	17
8	Air Canada Right-Hand Aft Engine Fastener - Patched Area at Forward End	18
9	Air Canada Right-Hand Aft Engine Fairing - Typical Fastener Holes	18
10	Air Canada Right-Hand Aft Engine Fairing - Badly Elongated Hole	19
11	Air Canada Right-Hand Aft Wing-Body Fairing - 0.3 cm (1/8 in.) Crack	19
12	TWA Right-Hand Wing-Body Fairing - Typical Fastener Holes with Slight Fraying	23
13	TWA Right-Hand Wing-Body Fairing - Fastener Holes on Lower Edge with Mark-off	23
14	TWA Right-Hand Underwing Fillet - Fasteners Holes with Fraying	24
15	TWA Left-Hand Aft Engine Fairing - Typical Fastener Holes	24
16	TWA Left-Hand Wing-Body Fairing-Tape Patch Repair of Couged Area	25

FLIGHT SERVICE EVALUATION OF KEVLAR-49
EPOXY COMPOSITE PANELS IN WIDE-BODIED
COMMERCIAL TRANSPORT AIRCRAFT

Seventh Annual Flight Service Report

INTRODUCTION AND BACKGROUND

The subject program on flight service evaluation of Kevlar-49 fairings consists of fabrication, installation, and flight service evaluation of six secondary structural panels on each of three L-1011s. The three participating airlines are Eastern, TWA, and Air Canada. Fabrication and installation of the panels was completed in February 1973, with initiation of flight service occurring in early 1973 on all three aircraft.

In all of the prototype fairings, Kevlar-49 fabric comparable in fabric weave and thickness per ply to the baseline fiberglass, was substituted for the fiberglass on a ply-for-ply basis. This required no other design changes or development of new tooling for layup and cure, but still provided a savings in component mass of 25-30 percent. These six parts are as follows:

- A left-hand and right-hand set of large 152- by 170-cm (60- by 67-inch) sandwich wing-body fairing panel. The exterior skin is 0.05 cm (0.02 in.) thick with one ply of 181 style Kevlar-49 fabric and two plies of 120 style Kevlar-49 fabric. The interior skin is 0.04 cm (0.015 in.) thick with three plies of 120 style Kevlar-49 fabric. The honeycomb core is Nomex with 0.3 cm (1/8 in.) cells, and 0.05 gm/cm³ (3.0 lb/cu ft) density. Overall panel thickness is 2.24 cm (0.88 in.), with a solid laminate edge 0.25 cm (0.10 in.) thick, built up of 181 style Kevlar-49 plies (Figure 1).
- A left-hand and right-hand set of a small 23- by 84-cm (9- by 33-in.) solid laminate underwing fillet panel. The laminate incorporates nine plies of 181 style Kevlar-49 fabric and is approximately 0.25 cm (0.1 in.) thick (Figure 2).
- A left-hand and right-hand set of an aft engine sandwich fairing 76- by 183-cm (30- by 72-in.) approximately. The skins are 0.05 cm

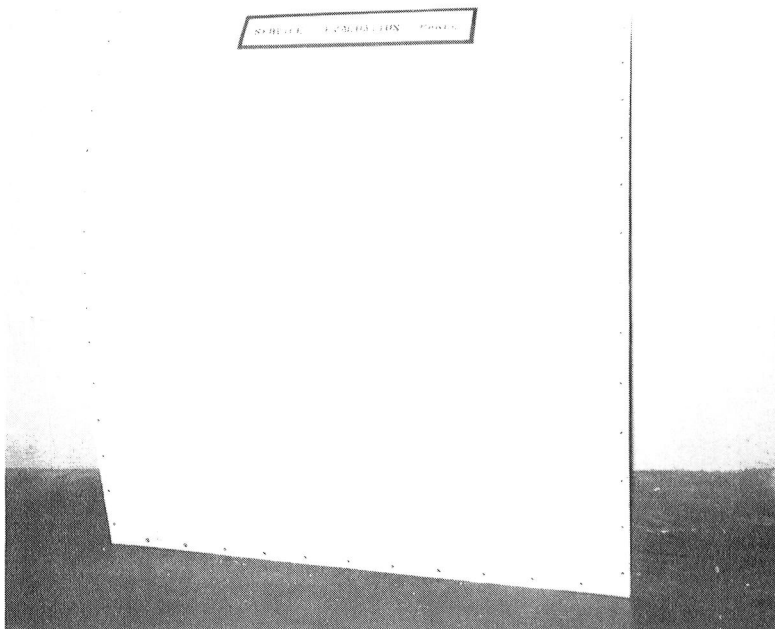


Figure 1. - Right-Hand Wing-Body Fairing Panel

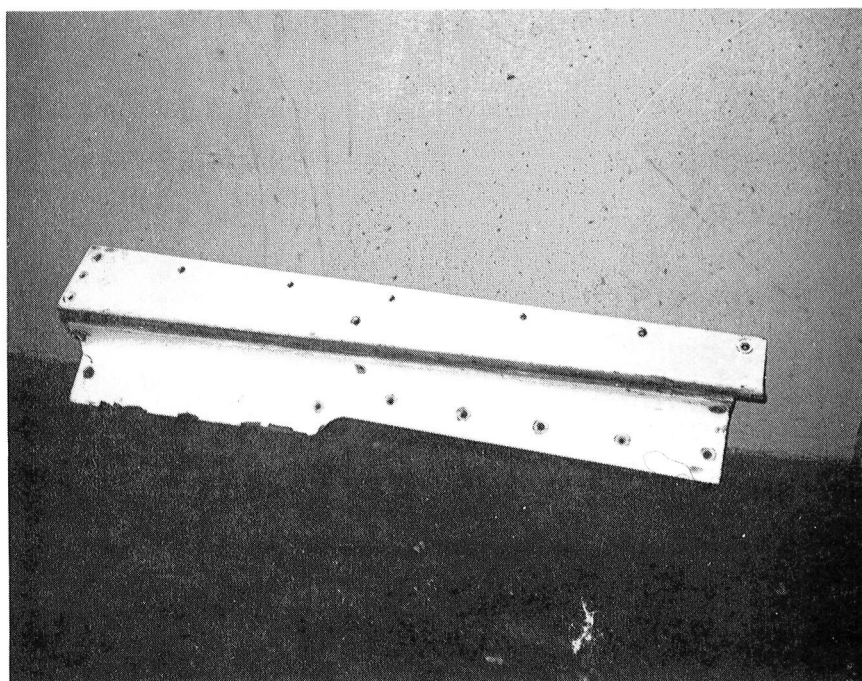


Figure 2. - Right-Hand Underwing Fillet Panel

(0.02 in.) thick with one ply of 181 style Kevlar-49 fabric and two plies of 120 style Kevlar-49 fabric. The Nomex core is identical to that used in the wing-body fairing except for thickness, and the overall panel thickness is 0.64 cm (0.25 in.). The aft engine fairing also has a solid laminate edge member 0.25 cm (0.10 in.) thick (Figure 3).

The Kevlar-49 panels used the same resin system as the production fiberglass parts. A 394 K (250°F) curing, 355 K (180°F) service epoxy (Hexcel's F-155) was used in the wing-body fairing and under-wing fillet panels; and a 450K (350°F) curing, 422 K (300°F) service epoxy (Hexcel's F-161) was used in the aft engine fairings. Two fabric weave styles of Kevlar-49 were used. The Kevlar-49 style 181 is an 8-harness satin weave similar to the 181 fiberglass weave, 0.23 mm (9 mils) per cured ply and 0.17 kg/m² (5.0 oz/yd²) dry mass. Kevlar-49 style 120 is a plain weave, 0.13 mm. (5 mils) per cured ply and 0.06 kg/m² (1.8 oz/yd²) dry mass. Both fabric styles incorporate light denier Kevlar-49 yarns, 380 denier for style 181, and 195 denier for style 120. The heavy denier yarns used in styles 281 and 285 Kevlar-49 fabric had not been developed at the time these parts were made.

All of the parts have an outer layer of flame-sprayed aluminum and top-coat applied according to standard production procedures used on the baseline fiberglass parts. The actual savings in component mass achieved by this direct substitution of Kevlar-49 for fiberglass averaged 26 percent for the six parts. Further details on Kevlar-49 part design and fabrication are given in NASA CR-112250 (reference 1), which is the final report of the fabrication and installation phases of the program.

The first annual inspection results are given in NASA CR-132647 (reference 2). The Air Canada and TWA panels were inspected at Lockheed in this case due to special circumstances, while Eastern personnel inspected the Eastern panels at their Miami Maintenance Base.

For the second annual inspection and all subsequent inspections, the program scope was expanded as follows to obtain more complete information and documentation of part conditions:

- A Lockheed Engineering representative is present for each annual inspection at the airlines' maintenance bases.

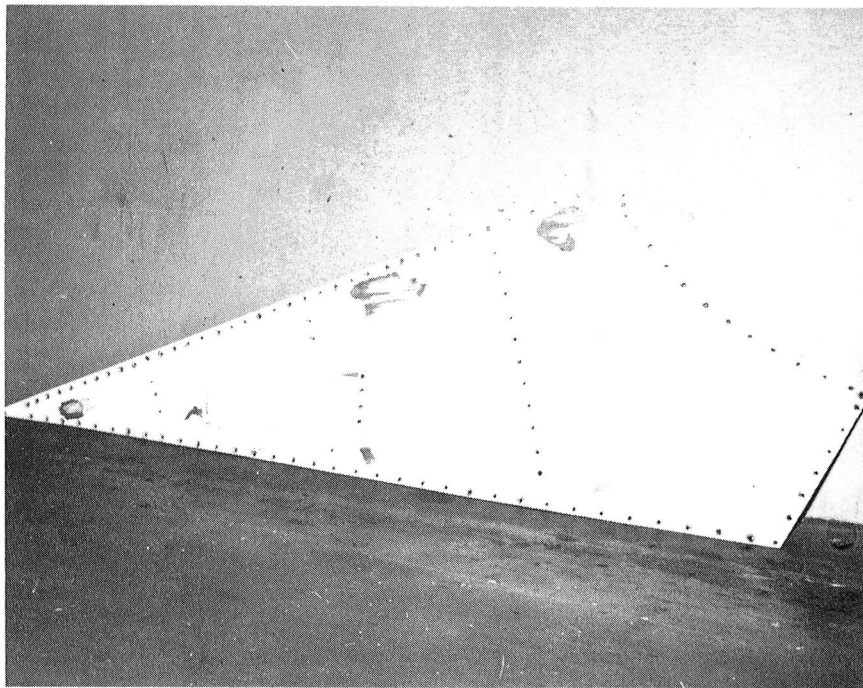


Figure 3.- Left-Hand Aft Engine Fairing Panel.

- Three of the six panels (one of each left-hand and right-hand set) are removed for thorough inspection, weighing, and inspection of fastener holes and interior surface conditions.
- The airlines provide reports to Lockheed on all incidences of damage and repair occurring in service.

The second, third, fourth, fifth and sixth annual inspections were conducted in accordance with this expanded scope, and are reported in NASA CR-132733 (reference 3), NASA CR-145141 (reference 4), NASA CR-145326 (reference 5), NASA CR-159071 (reference 6), and NASA CR-159231 (reference 7).

As discussed in previous reports, the TWA panels were removed after approximately 1 year (2400 hours) of service, and reinstalled on a second TWA L-1011 for continuation of flight service testing. The reinstallation on TWA aircraft N31030 required some rework and repair of the panels, particularly in the case of the aft engine fairing panels, where relocation of all fastener holes was required. This rework activity is reported in detail in the Second Flight Service Report (reference 3). The aircraft on which these parts were installed was delivered to TWA in August 1975, and have since been inspected annually in accordance with the expanded program scope.

During 1977, a 5-year extension to the program was received from NASA for a total of 10 years flight service of the Kevlar-49 fairings. This extension carries the program through 1983, and annual inspections of the three shipsets will take place in accordance with the expanded program scope outlined above.

In 1978, Eastern disclosed plans to lease the aircraft with the Kevlar fairings to a foreign carrier, but stated a willingness to reinstall the fairings onto a second aircraft. Additional funding was received for this reinstallation. Removal of the panels took place in 1979 and was discussed in the Sixth Flight Service Report (reference 7). The panels were reinstalled onto the second aircraft during 1980, and this activity is discussed in this report.

The fairings being evaluated in this program are the earliest Kevlar-49 components placed in commercial airline flight service, predating production applications of Kevlar-49 on commercial transports by several years. These

components are exposed to over 2000 flight hours per year of typical aircraft operating environments; and detailed monitoring of the fairings' performance in this program provides information on long-term durability, damage tolerance, chemical resistance, and mechanical properties. Kevlar-49 fibers are the only organic reinforcing fibers used in aircraft structures, and have certain characteristics, such as moisture pickup in the fiber and low resin/fiber bond, which were of concern initially. The resistance of Kevlar-49 composites to long-term service environment as verified by the 7 years of flight service in this program provides confidence in the use of Kevlar-49 for additional aircraft structural applications.

PANEL INSPECTIONS

The seventh annual inspection of the Air Canada fairings on Ship CF-TNB-502 (Serial No. 1021) took place on June 9, 1980 at the Montreal Maintenance Base. The left-hand wing-body fairing panel, the left-hand underwing fillet panel, and the right-hand aft engine fairing panel were removed for inspection, while the opposite set of panels were inspected on the aircraft. This was the opposite set to those removed in the previous inspection. The fairings at the date of inspection had been in-service for seven years, and had accumulated 17,440 flight hours. In the 12.5 months since the previous inspection, the fairings had accumulated 2860 hours.

The inspection of the TWA fairings on Ship N31030 (Serial No. 1111) took place at TWA's Los Angeles Maintenance Base on September 21, 1980. The right-hand wing-body fairing panel, the right-hand underwing fillet panel, and the left-hand aft engine fairing panel were removed for inspection, while the opposite set of panels were inspected on the aircraft. These were the opposite parts to the wing-body and aft engine fairings removed in the previous inspection. The TWA right-hand underwing fillet, however, is being removed at every inspection through the remainder of the program to obtain accurate mass determinations and detect any indication of continuing moisture pickup. Difficulty has been encountered in obtaining accurate mass determinations of the parts because of the lack of accurate balances at the airline maintenance bases. The proximity of TWA's base to the Lockheed plant makes it feasible to

bring in an accurate balance for the inspections. The sandwich panels are too large to weigh on this balance, but the underwing fillet can be readily weighed. This activity was initiated in 1978 on the right-hand part.

The fairings had 14,736 flight hours on Ship 1111 as of the date of inspection. These fairings had been initially installed on Ship 1026, and accumulated 2404 flight hours on that ship prior to removal and reinstallation for a total of 17,140 flight hours. The parts had accumulated 3892 hours in the 11 months since the previous inspection.

Inspection of these panels was by visual examination and coin tapping for delaminations and skin-core disbonds. The panels taken off the aircraft were cleaned to remove excessive dirt and residue. The panels were then inspected for the condition of the fastener holes and the inner surface, as well as the outer surface condition which was checked on all six parts.

The inspections were conducted with the participation of Lockheed Engineering, and with the assistance of airline maintenance personnel in removal and reinstallation of the panels. Photographs were taken of all panels and areas containing defects, damage, or other conditions of special interest. Photographs were provided by Air Canada in Montreal, and by the Lockheed Photography Department at TWA in Los Angeles. Detail observations at the inspections are given in Appendices A and B.

There was no inspection of the Eastern fairings in 1980. As discussed in the Sixth Annual Report (reference 7), the Eastern panels were removed from Ship N316EA (Serial No. 1022) in September 1979. The two wing-body fairings and two aft engine fairing panels were reinstalled onto Ship N313EA (Serial No. 1020) during the first week of October 1980. The two underwing fillet panels have been misplaced by Eastern and will be reinstalled at a later date if they are found. Ship No. 1020 had 20,551 flight hours at the time the fairings were installed.

The reinstallation of the fairings proceeded without any serious problems. Ship 1020 was selected for installation of the fairings because it is part of the same lot of airplanes as Ship 1022, which increased the probability of a proper fit of the fairings onto the new aircraft. The fit of the

four components onto Ship 1022 turned out to be acceptable with no gaps and with no need for edge trimming. The fastener pattern of the fairings did not precisely match the pattern on Ship 1022, however, and all of the fastener holes were therefore filled with a glass filled epoxy resin and redrilled. After drilling, the holes were visually inspected and found to be relatively free of fuzz. The four components were repainted prior to installation.

DISCUSSION OF INSPECTION RESULTS

The Kevlar-49 panels continue to perform satisfactorily in service with no major damage or defects requiring corrective maintenance. Minor impact damage has occurred, primarily on the wing-body fairing sandwich panels, which are subject to ground handling damage and damage from runway objects. In several instances, the skins have been penetrated exposing the honeycomb. The airlines do not regard this as a serious occurrence as these are lightly loaded nonstructural components which only take aerodynamic loads. Damage is therefore left unrepaired for an indefinite period or else given a cosmetic repair.

The only new incidences of damage noted in the 1980 inspections were:

1. Several very slight gouges on the forward edge of the Air Canada left-hand wing-body fairing.
2. A small crack on the inner surface of the same part.
3. Two slight indentations on the inner surface of the TWA right-hand wing-body fairing.
4. A very small crack on the exterior surface of the TWA left-hand wing-body fairing.

All but the last of these are unlikely to have occurred during normal service, and very likely occurred during the removal and reinstallation operations. This illustrates the fact that the frequent removal and reinstallation of these test panels and the resultant greater amount of handling increases the likelihood of maintenance damage compared to regular service components.

None of the various damage areas noted in previous inspections were observed this time to have propagated or increased in extent. This lack of damage growth is a significant indication of acceptable damage tolerance for Kevlar-49 in these applications, and in some cases the damage has remained unchanged in appearance or size for five years.

While some of the minor damage observed to date has not been repaired, several repairs have been made to the Kevlar-49 parts, mostly on the exterior surfaces of the wing-body fairing sandwich panels. In previous inspections, repairs have been noted in which cracks were filled with a resin filler and in one case coated with conductive paint. One patch consisted of aluminum speed tape with an overcoat of paint, and in other cases a tape overlay appears to have been applied. A patch overlay has also been noted on the inner surface of one of the wing-body fairings. Two new repairs were noted in the 1980 inspections: a resin overlay on the inner surface of a wing-body fairing, and a tape patch repair of a deep gouge on another wing-body fairing. These new repairs are typical of the repairs observed in earlier inspections.

In summary, the repair procedures used on the fairings have been cosmetic field repairs typical of the procedures used for noncritical fiberglass parts, and adaptable to either line station or maintenance base operations.

The other damage condition which has been typically observed on the Kevlar-49 panels has been fraying and elongation of fastener holes. These have been minor conditions in all instances, which have not required maintenance action or repair. Elongation of the fastener holes has occurred in a random distribution, and has been noted primarily on the underwing fillet panels. The condition is comparable to hole elongation on similar fiberglass panels which is a fairly common occurrence according to the airlines. The cause of elongation is concentrated or nonuniform bearing loads possibly resulting from installation problems. There has been relatively little increase in the incidence or severity of this elongation, and in the 1980 inspections no significant increase in elongation was observed over the 1979 results.

The fastener hole fraying appears to be a general occurrence on Kevlar-49 holes and edges where less than optimum machining procedures have been used. The fraying noted on these parts appears to be primarily the result of the

initial machining operation, as this condition has remained essentially unchanged with increasing service life. These parts were fabricated in 1972 when development of Kevlar-49 machining techniques was in a very early stage, and the degree of fraying may therefore be more severe than for currently fabricated parts. In previous inspections, it has been observed that some of the aft engine fairings and underwing fillets have noticeably less fraying than others. This indicates that variations in machining techniques and operator skills at the time of installation was a significant factor in the degree of fraying. It has also been noted that the elongated holes in the underwing fillets generally have more fraying than the other holes, indicating that in-service loads can aggravate the initial fraying. There is no evidence that the frayed condition in any way affects part performance.

A different type of damage was initially observed in 1977 on the right-hand TWA wing-body fairing. This was a large teardrop shaped disbond area 11.4- by 2.5-cm (4.5 by 1 inch) with an associated deep concave depression indicative of core crushing. The paint and flame spray were intact with no cracks or crazing. This disbond has not increased in area or depth since the 1977 inspection. A similar but smaller disbonded and depressed area was initially observed in 1976, and has not grown since the 1977 inspection. These occurrences, which are unique to this particular fairing, are probably related to a repair made when the part was reinstalled on Ship 1111 (reference 3). This repair was not documented, but apparently consisted of replacement of a damaged core area, extending partially through the core thickness, with a microballoon-filled potting compound. This is not therefore a Kevlar-49-related problem, but as it is a highly visible condition it is being monitored.

The Kevlar-49 parts have not been affected to any discernible degree by exposure to Skydrol or other aircraft fluids, but the presence of Skydrol has been observed on all three components. The Skydrol appears to have attacked a vapor barrier coating on some of the aft engine fairings. Paint adhesion to the Kevlar-49 surfaces appears to be comparable to fiberglass parts, as would be expected.

The Kevlar-49 parts have been weighed on the occasions when they have been removed. The effects of paint loss, repainting, resealing, and repair have masked any mass change due to moisture pickup; and determination of mass changes has been hampered by the lack of suitable balances at the airline maintenance bases. A balance has been brought from Lockheed to the TWA base in Los Angeles for weighing of the small underwing fillet panel in the last three inspections. Accurate mass determinations have been obtained on the right-hand fillet (Appendix B), and the mass of this part will be monitored throughout the remainder of the program. Results to date show no significant weight change over two years; and the part apparently had reached moisture equilibrium by the time the weighings started in 1978, as would be expected.

SUMMARY OF RESULTS AND CONCLUSIONS

The Kevlar-49 fairing panels continue to perform satisfactorily and are free of major damage or defects after 7 years of service and a total of 52,000 flight hours on the three aircraft.

Two types of minor damage have been noted: cracks resulting from impact observed principally on the wing-body fairings; and fraying and elongation of fastener holes. The cracks are primarily the result of ground handling damage, while the fastener hole fraying and elongation appears to be primarily the result of the initial drilling and installation procedures, aggravated in a few instances by in-service loads. The absence of crack growth or significantly increased hole elongation, and the random limited occurrence of the hole elongation indicates that Kevlar-49 is resistant to damage propagation under the relatively light loading conditions typical of fairings. The fastener hole fraying is the only damage condition observed on the Kevlar-49 parts which is not also typical of similar fiberglass parts. The fraying has not increased in severity with increasing service life, and does not have any apparent effect on part performance.

The Kevlar-49 panels have been free of delaminations, and only a few minor skin-core disbonds have occurred. No defects have been observed which can be attributed to moisture or other environmental factors. These findings

indicate that two properties of Kevlar-49 which have been of concern - the poor resin-fiber interface bond and the moisture pickup of the Kevlar-49 fibers - have not seriously affected part performance.

The repairs which have been performed on these parts are typical cosmetic repairs, such as resin filling of surface cracks and applications of tape over damage areas. This type of repair is typically performed on fiberglass secondary structures, and these observations indicate that Kevlar-49 parts can be repaired in the same manner as fiberglass parts.

In summary, Kevlar-49/epoxy appears to provide service life and structural performance for lightly loaded secondary structures equivalent to that of fiberglass/epoxy.

APPENDIX A
DETAIL OBSERVATIONS OF
KEVLAR-49 FAIRING PANELS -
AIR CANADA SHIP CF-TNB-502 (SERIAL 1021)
JUNE 1980

Three of the six fairing panels were removed for inspection: the left-hand wing-body fairing and underwing fillet panels, and the right-hand aft engine fairing. The other panels were inspected in place on the aircraft. No mass determinations were obtained at this inspection.

LEFT-HAND WING-BODY FAIRING

1. A deep gouge in the upper center area of the panel exterior, 0.4- by 0.6- cm (5/32- by 1/4-inch), had not changed in size or appearance since the previous inspection (Figure 4). This was first observed in 1978.
2. A gouged area on the lower forward edge was also observed initially in 1978, and had not changed in size or appearance since the 1979 inspection; but five additional gouges were noted on the lower forward edge. All of these were very limited in size and represented very slight damage.
3. A repair made between the 1977 and 1978 inspections had not changed in appearance. This was a repair of a 3.2 cm (1 1/4-inch) crack in the upper aft exterior surface first observed in 1974, and consisted of resin filler applied into the crack area followed by an overcoat of conductive paint. No propagation of this damage has occurred.
4. A crack 0.8 cm (5/16 in.) in length on the inner surface upper forward area, first observed in 1978 had not changed in appearance or extent. Another crack was noted on the inner surface in the upper

aft area 1.3 cm (1/2-in.) in length with an associated delaminated area 0.95- by 1.3- cm (3/8- by 1/2-in.). This damage had not been observed previously (Figure 5).

5. An overlay or resin coat 22.9- by 2.5- cm (9- by 1-in.) in area was observed in the upper aft area on the inner surface. This had not been previously observed, nor had any damage been previously noted in this area.
6. Slight fraying was observed on all fastener holes, with a greater degree of fraying noted on the aft and lower edges. Slight elongation was noted on several holes on the upper, aft and lower edges. The holes on the lower edge had the greatest degree of fraying along with a distinct fastener mark-off and localized deformation on the inner surface around the holes (Figure 6). These conditions have not changed significantly since the 1976 and 1978 inspections.
7. Extensive paint loss was noted indicating possible Skydrol exposure. The flame spray was not intact (See Figure 4).

LEFT-HAND UNDERWING FILLET

1. No surface damage or defects were noted, although there was extensive paint loss, particularly in the upper section where the Kevlar-49 was almost completely exposed. The location of this part protects it from ultraviolet exposure however.
2. Slight fraying was observed on all fastener holes, and several holes were observed to be frayed to a greater extent than the others. Most of the fastener holes had at least a slight degree of elongation, and eight holes had a significant degree of elongation to 0.55 cm (7/32 in.) and in three cases to 0.6 cm (1/4 in.) from the original 0.5 cm (3/16 in.) dimension (Figure 7).

RIGHT-HAND AFT ENGINE FAIRING

1. No damage or defects were noted on either surface, but there was extensive paint loss indicating possible Skydrol exposure.
2. Two patch areas at the extreme forward and aft edges of the fairing were still unchanged in appearance since 1974 when they were originally observed. The patches are dark and fibrous, and may be some type of electrical tape overcoated with resin (Figure 8).

3. Slight fraying was observed on all fastener holes, but the degree of fraying on this component is less than that noted on any of the other Kevlar-49 aft engine fairings. About 1/3 of the fastener holes are noticeably more frayed than the other holes (Figure 9).
4. Several holes had a slight amount of elongation. Two holes were elongated to 0.55 cm (7/32 in.) from the original 0.5 cm (3/16 in.) diameter, and two holes were badly elongated to 0.7 (9/32 in.) diameter (Figure 10). This was out of approximately 100 fastener holes on the aft engine fairing, so the incidence of hole elongation was very minor.

RIGHT-HAND WING-BODY FAIRING

1. Two exterior surface cracks observed in earlier inspections had not propagated or changed in appearance. These were a deep 0.3 cm (1/8 in.) crack in the center area first observed in 1976, (Figure 11) and a 0.6 cm (1/4 in.) crack in the forward center area first observed in 1975. There were no other exterior surface defects or damage. The 0.3 cm crack had been circled by Air Canada Maintenance.

RIGHT-HAND UNDERWING FILLET

1. No exterior defects or damage was noted. Extensive paint loss was observed with about 50 percent of the Kevlar-49 exposed in the upper section. This indicates possible exposure to Skydrol.

LEFT-HAND AFT ENGINE FAIRING

1. No exterior surface defects, damage, or paint loss was observed.

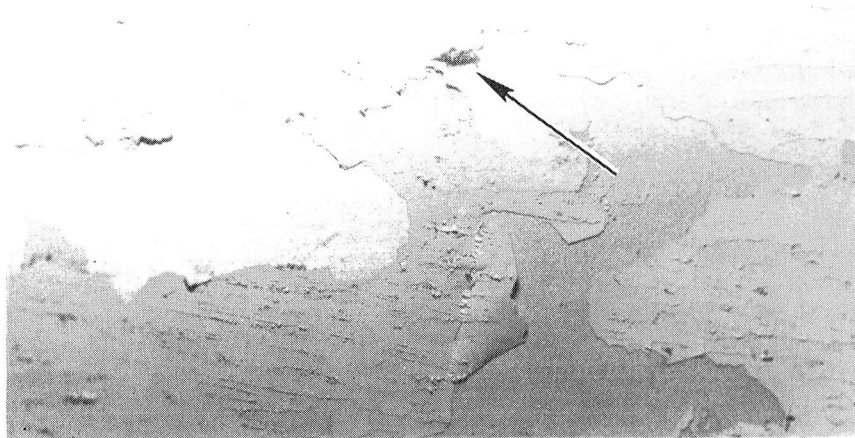


Figure 4. - Air Canada Left-Hand Wing-Body Fairing -
Deep Gouge 0.4 by 0.6 cm (5/32 by 1/4 in.).

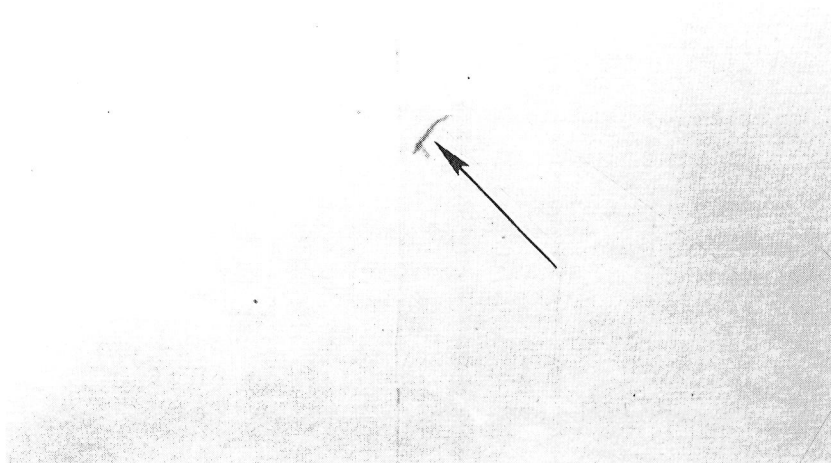


Figure 5. - Air Canada Left-Hand Wing-Body Fairing -
Inner Surface Crack 1.3 cm (0.5 in.) in Length.

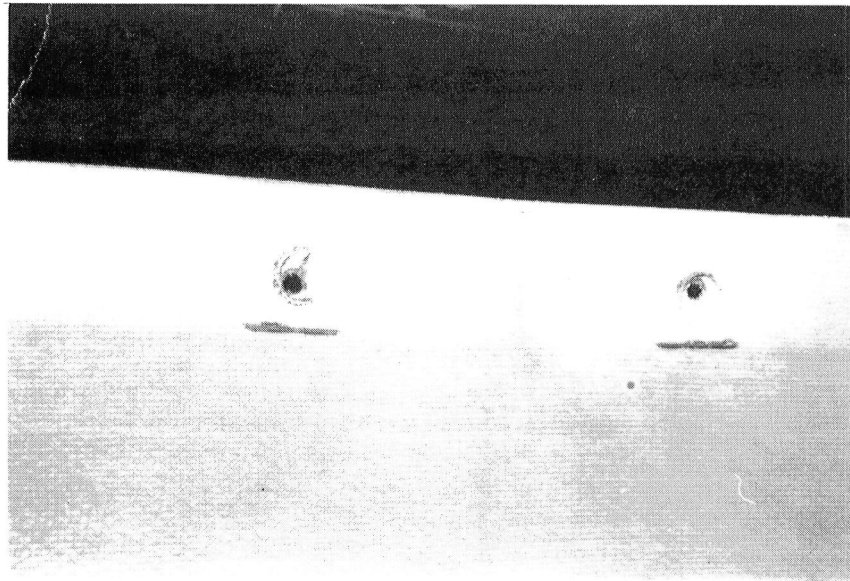


Figure 6. - Air Canada Left-Hand Wing-Body Fairing - Fastener Holes on Lower Edge with Mark-off.

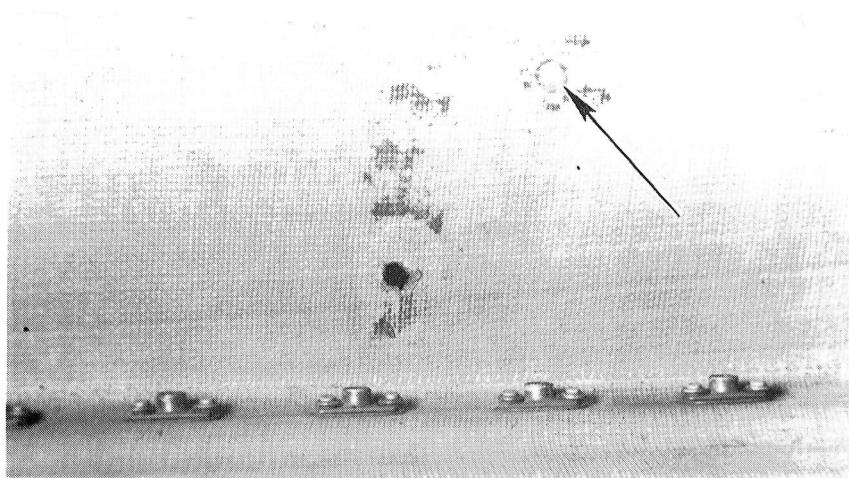


Figure 7. - Air Canada Left-Hand Underwing Fillet With Elongated Hole and Slight Fraying.

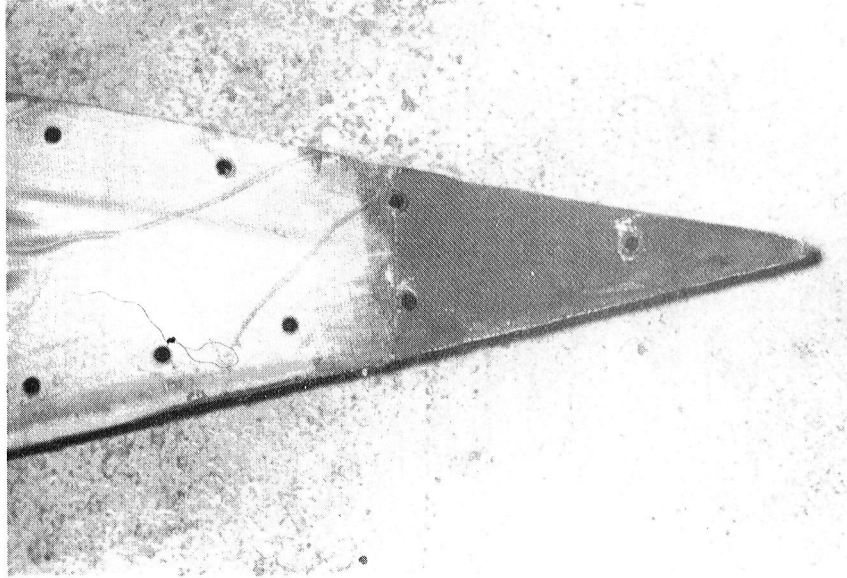


Figure 8. - Air Canada Right-Hand Aft Engine Fairing -
Patched Area at Forward End.

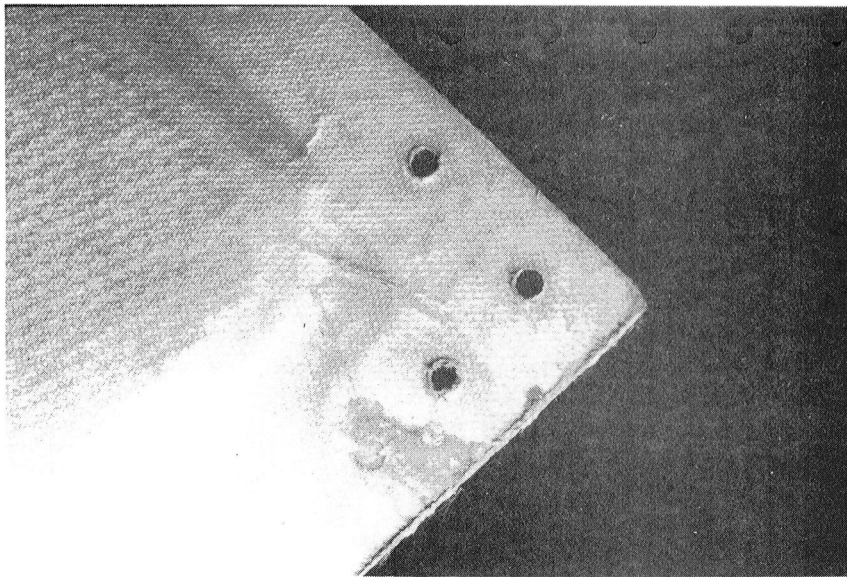


Figure 9. - Air Canada Right-Hand Aft Engine Fairing -
Typical Fastener Holes.

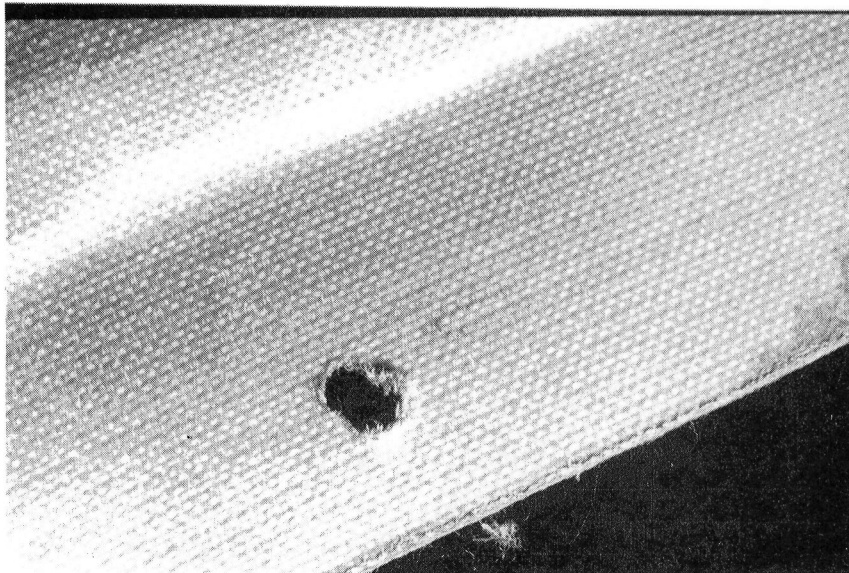


Figure 10. - Air Canada Right-Hand Aft Engine Fairing -
Badly Elongated Hole.

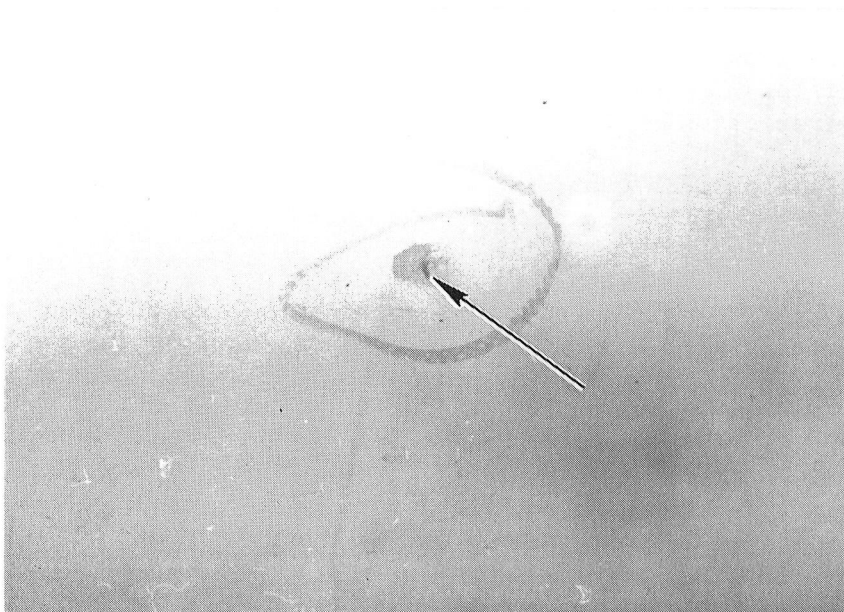


Figure 11. - Air Canada Right-Hand Aft Wing-Body
Fairing - 0.3 cm (1/8 in.) Crack.

APPENDIX B
DETAIL OBSERVATIONS OF
KEVLAR-49 FAIRING PANELS -
TWA SHIP N31030 (SERIAL 1111)
SEPTEMBER 1980

Three of the six fairings were removed for inspection: the right-hand wing-body fairing and underwing fillet panels and the left-hand aft engine fairing. The other panels were inspected in place on the aircraft. Mass determinations were made on the right-hand fillet panel.

RIGHT-HAND WING-BODY FAIRING

1. A large teardrop shaped disbonded and crushed area, 11.4- by 2.5- cm (4.5- by 1-in.) had not changed in size or appearance since the previous inspection. This was first observed in 1977, and is in the lower forward area of the exterior surface. A second disbonded area with a slight associated indentation, 5.1- by 1.3-cm (2- by 0.5 in.) also in the lower forward area of the exterior surface, was also unchanged in size or appearance.
2. A small crack 0.3 cm (1/8in.) in length on the exterior surface was still unchanged, and has not increased in size since initially observed in 1976. Another crack 0.95 cm (3/18in.) in length was noted in the lower aft area of the exterior surface, but it could not be determined whether this crack was in the skin or only in the paint.
3. A rectangular patch overlay 10- by 20-cm (4- by 8-in.) on the lower forward edge of the exterior surface was unchanged in appearance since the previous inspection. This was first observed in 1978, but no damage had been previously observed in that area.
4. Fraying was observed on most of the fastener holes to a slight degree (Figure 12). Fraying was more pronounced on the aft edge than the top and forward edges; but the lower edge had the greatest degree of fraying, with the five aft holes very badly frayed.

5. Several holes showed some degree of elongation, and 11 of these were on the aft and lower edges. Six holes were elongated to 0.55 cm (7/32 in.) from the original 0.5 cm (3/16 in.) diameter, and six were elongated to 0.6 cm (1/4 in.) diameter. Two of the elongated holes on the lower edge had been relocated at the time of reinstallation (reference 3), and the new holes had been drilled partially through a glass-filled resin filler. Fastener mark-off around the holes was noted to a slight degree on the upper, forward and aft edges; and to a significantly greater degree on the lower edge (Figure 13). This condition had not changed since the 1978 inspection. A bolted metal attachment (Figure 13) appears to be for drainage purposes and is not a repair.
6. Two slight indentations were observed on the inner surface, both in the the upper aft area, and both about 0.95-1.3 cm (3/8 to 1/2 in.) in diameter. These had not been observed previously.

RIGHT-HAND UNDERWING FILLET

1. The panel mass was 664.0 gm. (1.464 lbs.). The previous mass determinations were 664.6 gm. (1.465 lbs.) in the 1979 inspection, and 663.75 gm. (1.563 lbs.) in the 1978 inspection. This indicates that a moisture equilibrium condition had been attained in this part by 1978 as would be expected after 5 years service, and that no significant weight changes due to paint loss or rework has occurred since 1978.
2. No surface damage or defects were observed, but Skydrol was observed on the surface.
3. All of the fastener holes showed at least a slight degree of fraying, and eight were badly frayed (Figure 14). Eight of the holes had a significant degree of elongation, six of these to a 0.55 cm (7/32 in.) dimension and two to a 0.6 cm. (1/4 in.) dimension from the original 0.5 cm. (3/16.) diameter. Five holes had both the heavy fraying and significant elongation, but the two conditions did not match exactly.

LEFT-HAND AFT ENGINE FAIRING

1. No damage or defects were observed on either surface. Some paint loss was observed with bare Kevlar-49/epoxy which is therefore being exposed to ultraviolet. The presence of Skydrol was observed on the surfaces, and appeared to be attacking the vapor barrier coat on the inner surface.

2. The fastener holes showed very little fraying (Figure 15). All of the fastener holes were redrilled when this part was reinstalled (reference 2), and the drilling was performed after curing an outer layer of 120 fiberglass over both Kevlar-49 surfaces. The glass completely prevents the typical frayed condition of Kevlar-49 fastener holes.
3. About 1/3 of the fastener holes showed some elongation, and a total of 29 were elongated to a significant degree. One hole was extremely elongated to 0.95 cm (3/18 in.) from the 0.5 cm (3/16 in.) diameter; 10 holes were elongated to 0.6 cm (1/4 in.) diameter, and the remaining 18 holes were elongated to 0.55 cm (7/32 in.) diameter. The distribution of these elongated holes was random.

LEFT-HAND WING-BODY FAIRING

1. A deep gouge 1.3 cm (0.5 in.) in length first observed in 1978 had been repaired since the 1979 inspection by application of a tape patch (Figure 16). A crack 0.3 cm. (1/8 in.) long first observed in 1977 had also been repaired since the 1979 inspection by filling with resin. This was still detectable as a slight indentation. There were no records of these repairs.
2. Another crack 1.3 cm. (0.5 in.) in length was observed near the repaired gouge. This had not been observed previously.
3. Extensive paint loss was observed along with the presence of Skydrol.

LEFT-HAND UNDERWING FILLER

1. No surface damage or defects was visible, but one fastener was missing. Only the lower segment was visible.

RIGHT-HAND AFT ENGINE FAIRING

1. No observations could be made of this part.

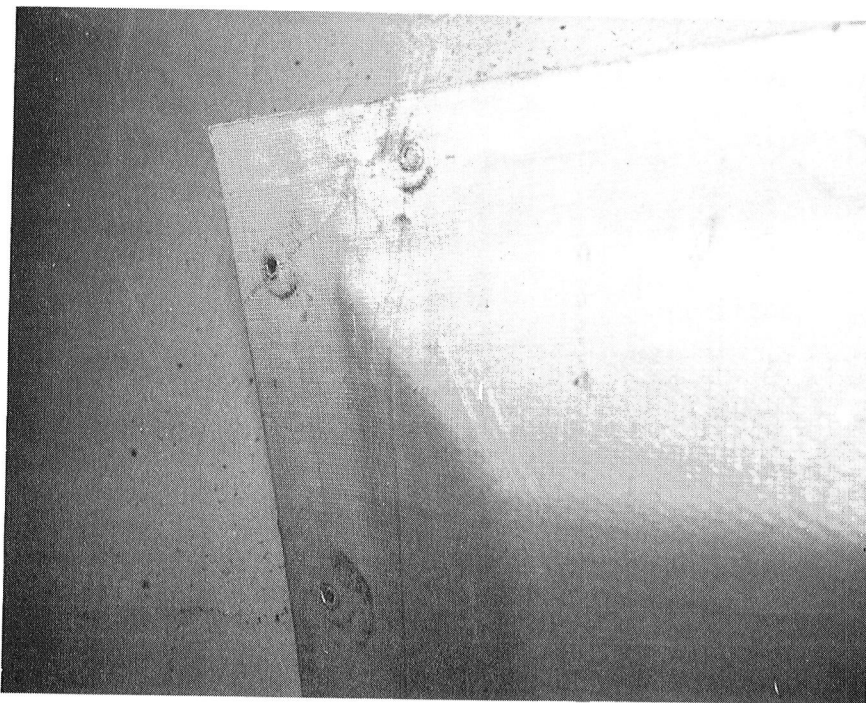


Figure 12.— TWA Right-Hand Wing-Body Fairing - Typical Fastener Holes With Slight Fraying.

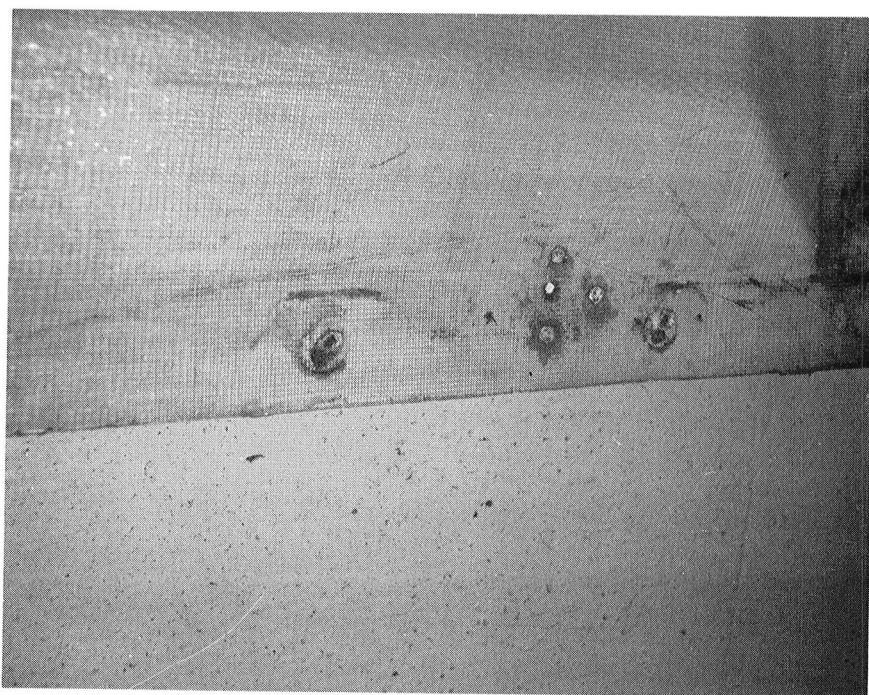


Figure 13.— TWA Right-Hand Wing-Body Fairing - Fastener Holes On Lower Edge With Mark-off (Also Showing Drainage Attachment).



Figure 14. - TWA Right-Hand Underwing Fillet -
Fasteners Holes With Fraying.



Figure 15. - TWA Left-Hand Aft Engine Fairing -
Typical Fastener Holes.



Figure 16.- TWA Left-Hand Wing-Body Fairing
Tape Patch Repair of Gouged Area.

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16. Abstract <p>Kevlar-49 fairing panels, installed as flight service components on three L-1011s, were inspected after 7 years' service. There are six Kevlar-49 panels on each aircraft: a left-hand and right-hand set of a wing-body sandwich fairing; a solid laminate under-wing fillet panel; and a 422 K (300°F) service aft engine fairing. The three L-1011s include one each in service with Eastern, Air Canada, and TWA. The fairings have accumulated a total of 52,500 hours, with one ship set having 17,700 hours service. The inspections were conducted at the airlines' major maintenance bases with the participation of Lockheed Engineering.</p> <p>The Kevlar-49 components were found to be performing satisfactorily in service with no major problems, or any condition requiring corrective action. The only defects noted were minor impact damage, and a minor degree of fastener hole fraying and elongation. These are for the most part comparable to damage noted on fiberglass fairings.</p> <p>The service history to date indicates that Kevlar-49 epoxy composite materials have satisfactory service characteristics for use in aircraft secondary structure.</p>					
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